DISAPPEARANCE OF DEAD PINK SALMON EGGS AND LARVAE FROM SASHIN CREEK, BARANOF ISLAND, ALASKA

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CONTENTS

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ABSTRACT

The abundance of dead 1961 brood year pink salmon eggs and larvae was observed from October 1961 to March 1963 in a small Southeastern Alaska stream, Sashin Creek. Dead eggs disappeared slowly from the spawningbeds between the end of spawning (October 1961) and the beginning of fry emergence (March 1962). Significant numbers of fragments from dead 1961 brood year pink salmon eggs were found in spawningbeds as late as March 1963. Dead 1961 brood year larvae decomposed more rapidly than eggs, disappearing from spawningbeds before August 1962.

Dissolved oxygen levels averaging near 50 percent of saturation were observed in Sashin Creek spawningbeds when decomposing eggs were present. The evidence did not contradict the hypothesis that decomposing eggs may impair water quality for more than 1 year beyond the date of spawning.

INTRODUCTION

Research to gain a better understanding of factors limiting production of pink salmon *(Oncorhynchus gorbuscha)* in fresh water has been conducted by the Bureau of Commercial Fisheries since 1934 in Sashin Creek near the southern end of Baranof Island, Southeastern Alaska. Spawning escapements of nearly 50,000 females with a potential deposition of about 100 million eggs have been observed on the 13,600 square meters of Sashin Creek spawning ground.

Production of pink salmon fry from selected segments of the Sashin Creek spawning ground was first evaluated in early 1960 (1959 brood year). The results suggest that steep-gradient segments of the spawning ground possess a greater potential to produce fry than shallow-gradient segments (Merrell, 1962).

Research on the fry production potential of spawning beds was expanded more recently at Sashin Creek to examine critically the relation between quality of the spawningbeds and the growth, development, and survival of young salmon prior to fry emergence. As a part of this research, mortality of eggs and larvae is estimated periodically in Sashin Creek spawningbeds. The measurement of mortality is made difficult in certain instances by the disappearance of eggs and larvae from spawningbeds because of factors such as gravel movements, decomposition, scavenging and predation. As pointed out by Kaganovskii (1949), McDonald (1960), and McNeil (1962a), these factors introduce bias to total mortality percentages calculated from live-dead ratios.

The processes of decomposition are significant because decomposing organic matter

competes with living organisms for oxygen in the water flowing within the gravel bed. Hunter (1959) suggested that dead eggs sometimes remained in spawningbeds for a year or more; with live eggs of the following brood year, these dead eggs placed an additional demand upon the available oxygen supply. Ricker (1962) also considered the question of residual decomposing eggs fouling spawningbeds after eggs of a subsequent brood year had been deposited, but he indicated that further study of the problem would be required before Hunter's hypothesis could be accepted or dismissed.

Changes in abundance of dead 1961 brood year pink salmon eggs and larvae were observed in Sashin Creek. The observations were made primarily to determine whether or not dead eggs or larvae remained in spawningbeds for a period of sufficient length to compete with eggs of a subsequent brood year for the available supply of dissolved oxygen.

Heavy spawning by pink salmon in Sashin Creek in 1961 produced a potential deposition of about 2,000 eggs per square meter. This was followed by an exceptionally light spawning in 1962, when the potential deposition by the three salmon species found in Sashin Creek (pink, chum, *O. keta,* and coho, *O. kisutch*) was less than 50 eggs per square meter in the most heavily spawned segments of the spawning ground.[1] It was thus possible to observe changes in abundance of residual dead eggs and larvae from a large spawning brood year which had only minimum disturbance from the spawning of adults in the subsequent brood year. The abundance of dead salmon eggs and larvae in Sashin Creek spawningbeds was measured in October 1961 (shortly after spawning); in March, July, August, and October, 1962; and in March 1963. Observations were also made on stream hydrology and water quality in spawningbeds. The findings are presented in this paper.

[1] The small pink salmon run of 1962 was the result of deliberate attempts to eliminate the even-year cycle from Sashin Creek.

METHODS

The Study Area

The study area encompassed 4,067 square meters (about 30 percent of the total available spawning area) and was centrally located in the parts of Sashin Creek accessible to adult salmon. The average gradient was 0.3 percent. The stream bottom was composed of materials containing 48 percent of particles larger than 25 mm., 44 percent between 1 and 25 mm., and 8 percent finer than 1 mm. The method of determining size composition of bottom materials is described in McNeil and Ahnell (1964).

Egg and Larval Abundance

Parents of 1961 brood year pink salmon spawned in Sashin Creek in September, and most of the surviving fry emerged the following April and May. The total potential egg deposition calculated from the average fecundity of adult females counted entering the stream was 29,425,000.[2] Twenty-nine percent of the calculated total deposition was estimated to have been available for deposition in the study area. This estimate was calculated from the fraction of total sightings of spawning adult pink salmon tagged at the weir and sighted in the study area. Results of the tagging indicated that spawners were distributed fairly uniformly throughout the Sashin Creek spawning ground, and the expected density of eggs was assumed to be nearly equal for all segments of the Sashin Creek spawning ground both inside and outside the study area.

Two areas outside of the boundaries of the study area were sampled in October 1961 to estimate the density of eggs present in spawningbeds at the end of spawning; but the study area was not sampled at this time. One of the areas sampled was located downstream and the other upstream from the study area. Potential egg deposition was estimated to be near 2,000 per square meter in these two areas as well as in the study area. Of the 2,000 eggs per square meter potentially available for

[2] Ninety-five percent confidence limits were ± 990,000.

deposition, about 1,100 eggs per square meter were estimated to be present in spawningbeds at the termination of spawning. This suggested that egg loss during spawning approached 50 percent.

A second population estimate was made in March 1962 just before fry emergence. At this time separate estimates were made for the study area by sampling 75 points and for the stream as a whole by sampling 254 points. About 1 percent of 16,000 eggs, larvae, and preemergent fry in samples collected from within the study area in March 1962 were identified as chum or coho salmon.

All sampling was done with a hydraulic egg and larval sampler. Circular areas of 0.2 square meter were sampled at points selected at random within the study area with the aid of random number tables. Because the mesh openings in the collection net were 2 mm. in diameter, few fragments less than 2 mm. maximum dimension were collected. For a more complete description of the equipment and techniques used to collect eggs and larvae and to calculate their abundance, the reader is referred to McNeil (1962a).

For each sample, dead specimens were classified in the following groupings:

1. Dead eggs
   a. Whole
   b. Fragments

2. Dead larvae

After the 1961 brood year fry had emerged in spring 1962, density of residual dead eggs and larvae was estimated in the study area. Estimates were made during early July, mid-August, and late October, 1962, and in mid-March 1963. The mid-August sampling was completed just before the chum salmon spawned and the late October and mid-March sampling was completed after small numbers of chum, pink, and coho salmon spawned (about 30 female chum, 4 female pink, and an unknown but small number of coho).

Although spawning was exceptionally light in 1962, there was evidence that 1962 brood year eggs introduced some error to later estimates of density of the 1961 brood year residual spawn. Chum salmon spawned mostly in late August 1962 when water temperatures were high (11° to 13° C.) and stream waterflows were low (less than 80 c.f.s.). Their potential egg deposition based on an assumed fecundity of 2,700 eggs per female (see Rounsefell, 1957) was about 20 eggs per square meter in 1962. There was evidence of early high mortality of chum salmon eggs accompanied by an initially rapid rate of decomposition, and this may have introduced error to estimates of density of residual dead 1961 brood year eggs made in October 1962 and March 1963. Pink and coho salmon eggs, deposited in autumn 1962, were easily separated from 1961 brood year eggs collected in the October 1962 samples. However, 1962 brood year eggs of these species may have decomposed and introduced error to estimates of abundance of 1961 brood year eggs made in March 1963.

All egg fragments larger than 2 mm. retained in the collection net were counted, but it could not be definitely established that each fragment counted represented the remains of a single egg. This problem became more acute as the season progressed, and population estimates from samples collected in August and October 1962 and March 1963 may have been biased upward because of it. In July samples, small oblong pieces of yolk classified as larval remains because they resembled the shape of a yolk sac may also have been misclassified. The remaining parts of a larva were no longer present and may have decomposed.

Stream Discharge and Temperature

The height and temperature of the stream water were recorded continuously. A water level recorder was located 700 feet upstream from the upper boundary of the study area, and a water temperature recorder 1,200 feet downstream from the lower boundary. No tributary creeks enter Sashin Creek between the two recorders. A Price current meter, which was calibrated by the U.S. Geological Survey, was used to gather water velocity data needed to establish a gage height-discharge relationship (rating curve) for Sashin Creek.

Water Quality

Near the beginning of the 1962 spawning season, mean levels of dissolved oxygen, free carbon dioxide, and ammoniacal nitrogen in the intragravel water[3] were estimated from water samples collected at randomly selected points. Water samples were obtained from standpipes similar to those described by McNeil (1962b) except that 1-inch inside diameter pipes were used instead of 3/4-inch.

The unmodified Winkler method was used to measure the amount of atmospheric oxygen dissolved in water samples. Samples were titrated with 0.022 N sodium thiosulfate solution delivered from a microburette. Final readings were corrected for the volumes of fixatives added to each sample.

Samples for free carbon dioxide were collected in sequence in two 30-ml. samples from each standpipe. Twenty-five ml. from each of the two samples were combined in a Nessler tube, giving a 50-ml. sample which was titrated to a phenolphthalein endpoint with N/88 sodium hydroxide to determine the amount of free carbon dioxide present.

A model 900-3 Klett-Summerson photoelectric colorimeter was used to determine ammoniacal nitrogen. Thirty-ml. water samples were collected from standpipes, and 25 ml. of the sample were carefully transferred from the collection vial to a 100-ml. test tube by pipetting. Two ml. of Nessler reagent were added to each sample, and color was permitted to develop for 5 minutes. The solution was then transferred to a 40-mm. colorimeter cell, and readings were taken with a 420-mμ color filter. Zero settings were made, using 25 ml. of ammonia-free distilled water plus 2 ml. of Nessler reagent. Zero was reset after each four samples.

The methods used are described further in "Standard Methods for the Examination of Water and Sewage" (10th edition, 1955).

[3] The term "intragravel water" is used here to describe water flowing through interstitial spaces within the spawning bed.

OBSERVATIONS OF EGGS AND LARVAE

Potential egg deposition by pink salmon in the study area during 1961 was estimated to be 8,533,000, an average density of 2,100 per square meter. A small undetermined number of chum and coho salmon also spawned here; but, as already reported, their progeny were only about 1 percent of the eggs and larvae collected in March 1962.

Changes in Abundance of the 1961 Brood Year

Estimated densities of 1961 brood year eggs and larvae in the study area through mid-August 1962 and before deposition of 1962 brood year eggs are summarized in table 1. Mean values of estimated densities of living and dead eggs or larvae are plotted in figure 1 to show trends in their abundance.

Total Population.--The total population of live plus dead 1961 brood year eggs and larvae in the gravel appeared to undergo two periods of sharp decline (fig. 1)--one corresponding to the period of spawning and the other to the period of fry emergence. Because of fairly high spawning densities in 1961 (1.1 females per square meter in the study area), losses from redd superimposition and other factors associated with spawning may have been high and probably accounted for much of the difference observed between estimated potential egg deposition and estimated density of eggs in the spawning bed at the end of spawning.

Evidence was obtained that the second period of sharp decline was caused by emergence of fry from the gravel. The total population of preemergent fry in Sashin Creek in March 1962 was estimated to include 6,300,000 live pink salmon.[4] At the termination of fry migration in mid-June 1962, 5,940,000 pink salmon fry had been counted leaving Sashin Creek. Hence, there was no evidence of high mortality during emergence and migration, and

[4] The 90-percent confidence limits of this estimate were ±1,090,000.

Table 1.--Estimated densities of 1961 brood year salmon eggs and larvae in Sashin Creek study area before deposition of 1962 brood year eggs

Date	Eggs and larvae per square meter					
	Total		Live		Dead	
	Mean	Ninety-percent confidence limits of mean	Mean	Ninety-percent confidence limits of mean	Mean	Ninety-percent confidence limits of mean
1961						
October 1	1/ 2,100					
October 25	2/ 1,101	±198	2/ 947	±186	2/ 156	±28
1962						
March 20	1,130	±204	605	±179	524	±127
July 5	190	±149	0		190	±149
August 13	98	±41	0		98	±41

1/ Based on estimated potential egg deposition.

2/ Estimates obtained by pooling data from two areas lying outside the boundaries of the study area (one upstream and the other downstream). They are assumed to be representative of the study area, since the potential egg deposition was estimated to be nearly the same over all of the Sashin Creek spawning ground and since estimates of total egg density within each of the two areas did not differ significantly.

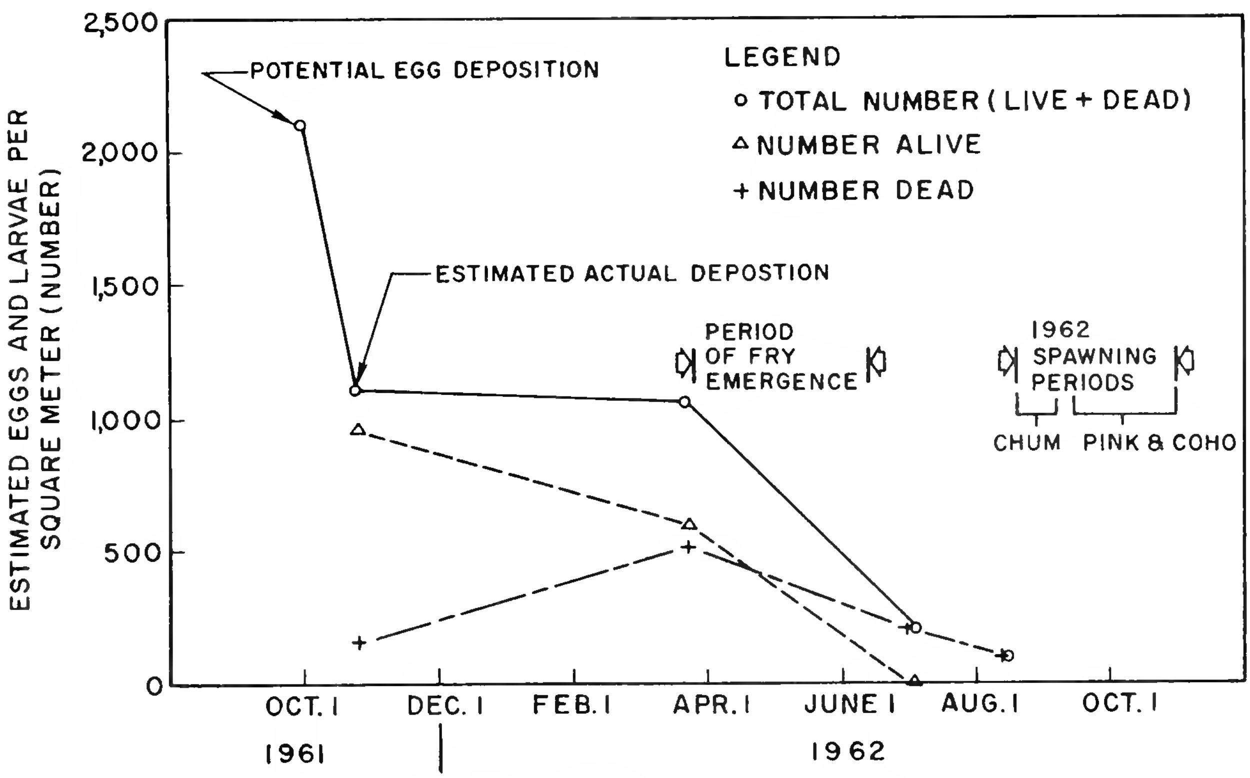

Figure 1.--Changes in abundance of 1961 brood year pink salmon eggs and larvae in Sashin Creek study area.

the major cause of declining abundance in the gravel between March and July 1962 was clearly determined to be the emergence and migration of fry.

Dead Eggs and Larvae.--Although the abundance of dead 1961 brood year eggs declined after hatching, sizable numbers of dead eggs were present in spawning beds 18 months after spawning (table 2).

About 14 percent of the eggs collected in the October 25, 1961, samples were classified as dead, but no fragments were recorded. All pink and chum salmon eggs remaining in March 1962 were dead because hatching had terminated at an earlier date. During the period October 1961 to March 1962, the abundance of dead eggs increased from an estimated mean of 156 to 420 per square meter. By mid-July 1962 the mean density of dead eggs had declined to an estimated 159 per square meter, and in August it declined further to 98 per square meter. Between August and November 1962, the declining trend reversed itself; and mean egg densities increased to 153 per square meter, the difference being significant at about the 10-percent level of probability. Two factors could have accounted for this apparent increase: (1) Early mortality of 1962 brood year chum salmon eggs which potentially added 20 eggs per square meter to the streambed and (2) disintegration of 1961 brood year eggs which increased the numbers of fragments counted and biased our estimates upward. In March 1963 the estimated mean density of dead eggs declined to 70 per square meter. Of these, 18 per square meter were whole eggs and were thought to be 1962 brood year eggs.

Dead larvae disappeared rapidly in comparison with eggs (table 2). In late March 1962, the estimated mean density of dead 1961 brood year larvae was 104 per square meter. By early July this number had declined to 31 per square meter. In mid-August 1962 no remains of larvae were found.

The estimated average abundance of dead 1961 brood year eggs and larvae (table 2) is plotted in figure 2. The curves are sketched in by eye. The curve showing changes in abundance of dead 1961 brood year eggs was drawn by assuming a zero point coincident

Table 2.--Estimated abundance of dead 1961 brood year eggs and larvae in the Sashin Creek study area

Date	Dead eggs per square meter		Dead larvae per square meter	
	Mean	Ninety-percent confidence limits of mean	Mean	Ninety-percent confidence limits of mean
1961				
October 25	156	±28	0	
1962				
March 20	420	±116	104	±43
July 5	159	±22	31	±6
August 13	98	±41	0	
October 29	1/ 153	±57	0	
1963				
March 10	1/ 70	±53	0	

1/ About 20 dead eggs per square meter were thought to be of the 1962 brood year.

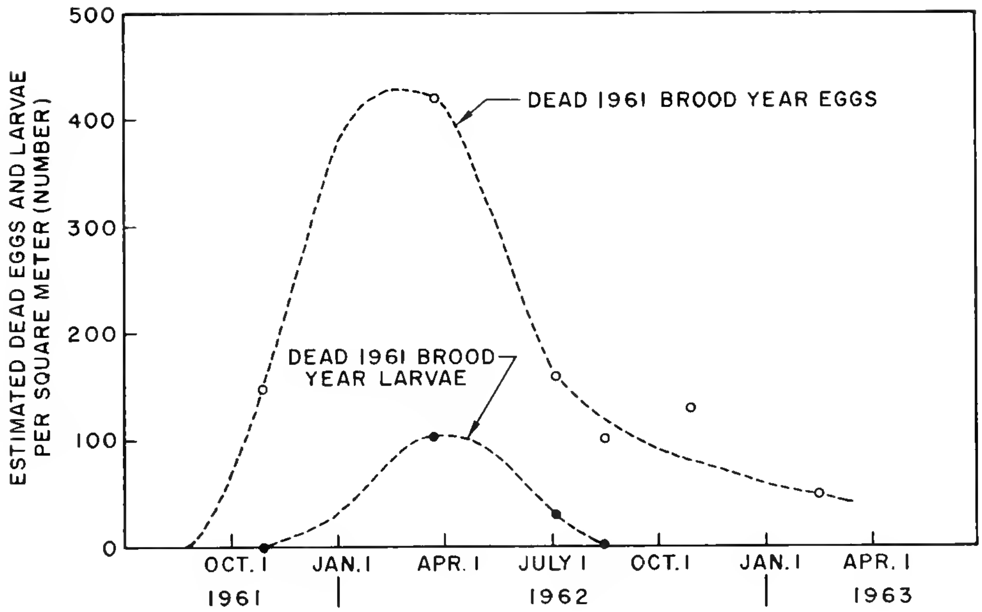

Figure 2.--Abundance of dead 1961 brood year pink salmon eggs and larvae in Sashin Creek study area.

with the beginning of spawning and a maximum point approximately coincident with the end of hatching. In plotting points for October 29, 1962, and March 10, 1963, we subtracted 20 eggs per square meter from the mean densities given in table 2 to adjust for presence of 1962 brood year eggs. The curve showing changes in abundance of dead 1961 brood year larvae was drawn by assuming a zero point at the beginning of hatching (a few live larvae were collected in the October 25, 1961, samples).

Composition of the Population of Dead Eggs and Larvae

Changes in the composition of the population of dead eggs and larvae in the study area were determined by analyzing changes in the percentages of (1) whole eggs, (2) egg fragments, and (3) larvae composing the total dead population. These percentages were calculated in the following manner (illustrated with the percentage of dead whole eggs in k samples):

$$\text{Percentage of whole eggs} = \frac{\sum_{1}^{k} \frac{\text{whole eggs}}{\text{total dead}}}{k} \times 100$$

Percentages of egg fragments or dead larvae were calculated by substituting one class or the other for whole eggs in the above equation.

Since samples contained dead specimens in unequal numbers, it was necessary to consider the problem of weighting for binomial variation. Samples containing less than 10 dead specimens were excluded from the analysis to minimize the necessity of applying unequal weights. A method described by Cochran (1943) was used to determine the weighting procedure that would provide the most efficient analysis of the larger samples, that is those containing 10 or more dead specimens. Equal weights were found to provide the most efficient analysis and were used in the present study.

Percentages of dead whole eggs, egg fragments, and larvae in samples are given in table 3. These data are plotted in figure 3 for the 1961 brood year. It appeared that dead 1961 brood year larvae were no longer present after the first week of August 1962. Also, at about the same time the population of dead 1961 brood year eggs comprised mostly fragments. In drawing figure 3, we assumed that the observed increase in the percentage of dead whole eggs after August 1962 reported in table 3 was due to mortality of 1962 brood year eggs.

Table 3.--Estimated percentages of whole eggs, egg fragments, and larvae in population, Sashin Creek study area

Date	Percentages of dead whole eggs		Percentages of egg fragments		Percentages of dead larvae	
	Mean	Ninety-percent confidence limits of mean	Mean	Ninety-percent confidence limits of mean	Mean	Ninety-percent confidence limits of mean
1962						
March 20	64	±5	20	±3	16	±5
July 5	34	±7	53	±9	13	±9
August 13	5	±3	95	±3	0	
October 29	1/ 25	±9	75	±9	0	
1963						
March 10	1/ 8	±10	92	±10	0	

1/ Whole eggs were mostly of the 1962 brood year.

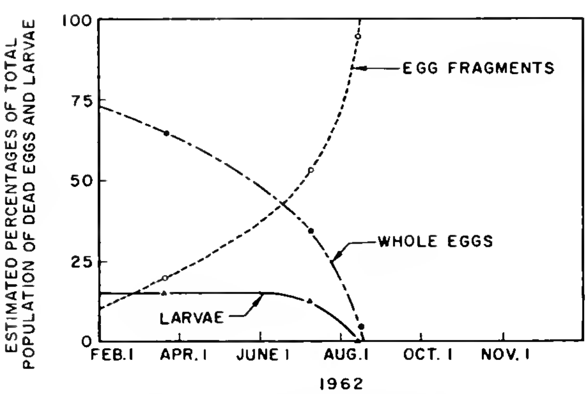

Figure 3.--Percentages of whole eggs, egg fragments, and larvae in population of dead 1961 brood year eggs and larvae in Sashin Creek study area.

OBSERVATIONS ON ENVIRONMENTAL FACTORS

Stream Temperature

Pink salmon eggs are deposited in late summer and early autumn as water temperatures decline; they hatch in autumn and early winter as water temperatures approach their lowest yearly levels; and fry emerge as water temperatures begin to rise the spring following egg deposition (Sheridan, 1962). Eggs of 1961 brood year Sashin Creek pink salmon were deposited as temperatures were declining from 13° to 10° C. Most hatching occurred at temperatures near 1° and 2° C., and fry emerged as temperatures were increasing from 2° to 8° C. Dead eggs of the 1961 brood year were subjected to temperatures as high as 16° C. in August 1962.

Weekly mean temperatures for the period October 1, 1961, through September 30, 1962, are plotted and compared with the long-term average weekly temperature for the same months (records cover 11 years) in figure 4. In 1961-62, autumn water temperatures tended to be below, and winter, spring, and summer water temperatures tended to be above the 11-year average. On the whole, water temperatures in 1961-62 were above normal and may have favored a higher than average decay rate.

Stream Discharge

Over the period of this study (October 1961 through March 1963) the discharge of Sashin Creek ranged from 10 to 570 c.f.s. Over an 11-year period, 10 c.f.s. is the approximate minimum flow recorded in winter. The maximum discharge (recorded in autumn 1954) is 620 c.f.s.

Considering again the period from October 1 through September 30, we find that dis-

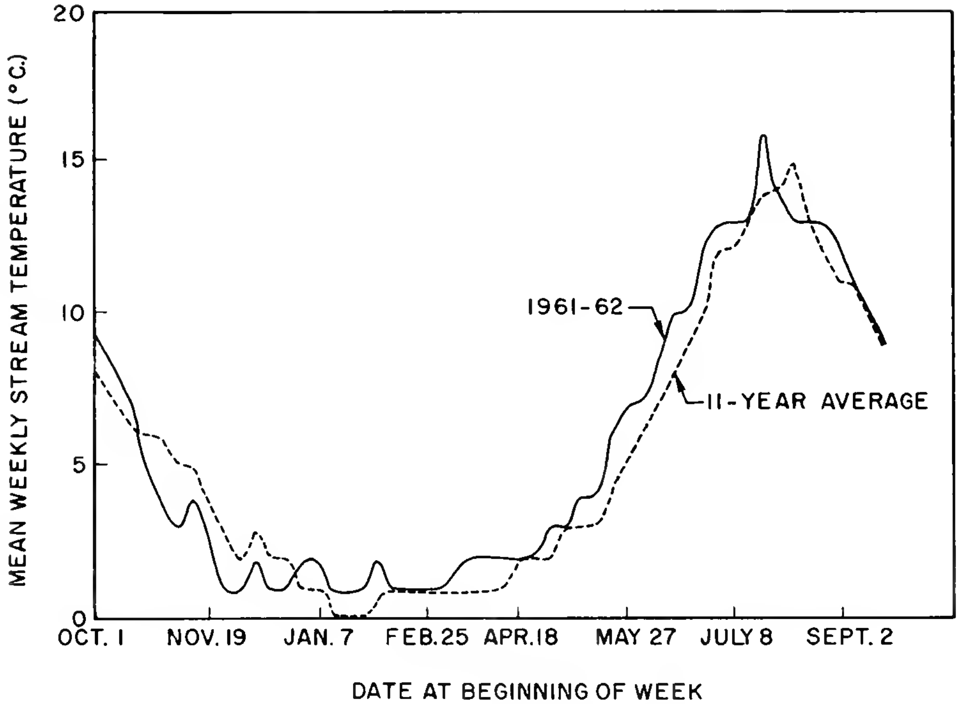

Figure 4.--Comparison of 1961-62 mean weekly temperature with long-term average of Sashin Creek over the period October 1 to September 30.

charges of less than 20 c.f.s. occurred during 47 days in 1961-62, compared with the 11-year average of 42 days. Discharges in excess of 500 c.f.s. occurred on only one occasion in 1961-62, compared with an 11-year average of 2.4 times. We conclude, therefore, that the periods of low streamflow in 1961-62 were near the long-term average, but extreme high discharge occurred less frequently than in an average year.

Water Quality

Concentrations of dissolved oxygen, free carbon dioxide, and ammoniacal nitrogen in intragravel water samples taken from the same 24 randomly selected points were measured in late August 1962 (table 4). These data are considered here since they describe water-quality conditions known to be associated with a population of almost 100 dead eggs per square meter.

Dissolved oxygen levels of intragravel water in the Sashin Creek study area were less than those reported for three other Southeastern Alaska streams 4 out of 5 years (McNeil 1962a, 1962b). During August when water temperatures were near 13° C., McNeil observed mean dissolved oxygen levels ranging from 6 to 8 mg./l. in 1956, 1958, 1959, and 1960. In August 1957, oxygen levels averaged only 3 to 4 mg./l., and a high early mortality of pink salmon eggs occurred shortly after spawning. Moreover, Phillips and Campbell (1962) found that embryos of coho salmon and steelhead trout *(Salmo gairdneri)* in Oregon streams suffered high mortality when oxygen levels in the spawning bed averaged less than 8 mg./l. These authors found that under field conditions dissolved oxygen levels were directly related to egg survival.

A period of low rainfall was thought to be an important factor contributing to the low dissolved oxygen levels in the intragravel waters studied by McNeil in August 1957. On the other hand, there was no evidence that hydrological conditions in Sashin Creek during August 1962 were unusual or unfavorable. Comparison of mean August water tempera-

Table 4. --Concentrations of dissolved substances in intragravel water samples taken from the same 24 randomly selected points in Sashin Creek, August 1962

Date of sample	Dissolved substance tested	Mean concentration of 24 samples	Standard error of mean
		Mg./l.	*Mg./l.*
August 23	Oxygen	1/ 5.0	0.57
August 24	Free carbon dioxide	9.0	0.94
August 25	Ammoniacal nitrogen (as NH_3)	0.44	0.11

1/ About 50-percent saturation at the prevailing stream temperature of 13° C.

ture and discharge of Sashin Creek in 1962 with the previous 10-year average revealed that nearly normal conditions prevailed in 1962:

	Water temperature	Discharge
	° *C.*	*C.f.s.*
1952-61	13.6	60 (range 15-112 c.f.s.)
1962	13.8	40

Based on the rather low levels of dissolved oxygen and the rather high levels of free CO_2, high biochemical oxygen demand (B.O.D.) was being satisfied in the Sashin Creek study area during late August 1962. It was not possible to determine the effect of decomposing 1961 brood year eggs on the total B.O.D. because water samples were not collected from a suitable control area. The possibility that decaying 1961 brood year eggs materially influenced the total B.O.D. cannot be ignored, however, and the problem warrants further study.

DISCUSSION AND CONCLUSIONS

The question of disappearance of salmonid eggs because of decomposition or scavenging has received attention by a few workers. Dead sockeye salmon eggs remained recognizable in a Bristol Bay stream for 1 year (Mathisen, 1962). In California, Briggs (1953) placed dead salmon eggs and larvae in permeable containers and buried them in a streambed. Among the test eggs, 1 percent were gone after 30 days, 9 percent after 60 days, and 13 percent after 90 days. Test larvae disappeared more rapidly than eggs. Gangmark and Broad (1955) placed live chinook salmon (*Oncorhynchus tshawytscha*) eggs in permeable containers and buried them in a California stream. They found the number of living and dead eggs and larvae recovered after 45 days to be only 50 percent of the number of live eggs originally buried. In reporting the results of his classic study on survival of salmonid eggs and larvae in New Zealand streams, Hobbs (1937) noted that the disappearance of eggs due to decomposition and physical factors introduced bias to his estimates of mortality; but he felt that scavengers or predators were restricted to the surface gravels and did not

penetrate deeply enough to consume eggs or larvae. More recent evidence has shown, however, that a varied fauna is often associated with eggs and larvae in streambeds. McDonald (1960) found lamprey larvae, stonefly nymphs, and diptera larvae associated with masses of sockeye salmon *(O. nerka)* eggs buried in spawning gravel. He also observed that the rate dead eggs disappeared was related to gravel size, being higher in coarse than in fine gravel. Briggs (1953) found oligochaetes to be abundant in redds containing large numbers of dead eggs; and at Old Tom Creek, Southeastern Alaska, Ahnell (1961) found a variety of invertebrates to depths of 21 inches in salmon spawning riffles.

In Sashin Creek it would appear that disappearance of dead eggs from decomposition and scavenging progresses slowly between the end of spawning (October) and beginning of fry emergence (March), and dead larvae seem to disappear more rapidly than dead eggs. The evidence also suggests that in Sashin Creek the fraction of the total B.O.D. attributable to decomposing eggs may not be entirely satisfied before eggs of the following brood year are deposited. Dissolved oxygen levels of intragravel water were observed to be only 50 percent of saturation at a time when the population of residual dead eggs was estimated to be about 100 per square meter. Additional research will be required before it can be determined if the B.O.D. of this population of dead eggs was sufficient to reduce oxygen levels significantly. High levels of free carbon dioxide and ammoniacal nitrogen in intragravel water were also observed at a time when the population of dead residual eggs was estimated to be about 100 per square meter. High levels of free carbon dioxide are known to reduce the blood's affinity for oxygen (Bohr effect), and ammoniacal nitrogen when in the form of ammonia or un-ionized ammonium hydroxide is known to be highly toxic to fishes. Further research is required to establish the rates at which these waste metabolites are produced during the decomposition of dead eggs and larvae.

Although the carryover of residual dead eggs for at least 1 year beyond the date of spawning was observed to occur in Sashin Creek, the results of other studies suggest that the redd construction activities by female salmon cause the removal of organic detritus such as egg fragments from their nests. McNeil and Ahnell (1964) and Semko (1954) found that spawning salmon removed significant volumes of fine materials from spawning beds, and they gave evidence that the materials removed included much of the organic detritus present in the streambed at the time of spawning. However, the capability of a population of spawning adults to cleanse a spawning bed of fouling organic matter is unquestionably directly related to the density of females spawning. Small populations (similar to the one observed in Sashin Creek during 1962) would, therefore, be expected to remove only a small fraction of the organic detritus present; whereas large populations could conceivably remove nearly all organic matter in the streambed. Ricker (1962) was cognizant of this relationship when he pointed out that residual decaying eggs could possibly have an adverse effect on a subsequent brood year of small size. Additional study is needed to establish more clearly relations among density of spawning adults, conditioning of spawning beds, and survival of eggs and larvae.

SUMMARY

1. Pink salmon deposited an estimated 29.5 million eggs in Sashin Creek during summer and autumn 1961, giving a potential egg deposition in excess of 2,000 per square meter of spawningbed.

2. Changes in size and composition of the population of dead eggs and larvae of the 1961 brood year were observed over the period October 1961 through March 1963 in a selected study area encompassing about 30 percent of the total area available for spawning in Sashin Creek.

3. Residual dead larvae disappeared from the streambed within 2 months after fry emergence.

4. Residual dead eggs were collected in significant numbers 18 months after spawning, but decomposition had caused them to dis-

integrate within 12 months of their time of death.

5. Low levels of dissolved oxygen and high levels of free carbon dioxide and ammoniacal nitrogen in the intragravel water in summer 1962 may have been partly due to the B.O.D. of decomposing 1961 brood year eggs. The evidence did not contradict the hypothesis that the quality of the spawningbed environment can sometimes be reduced for periods in excess of 1 year by decomposing eggs.

LITERATURE CITED

AHNELL, WARREN HARRY.
1961. New methods for sampling bottom fauna and periphyton in salmon spawning gravels. Master of Science Thesis, University of Washington, Seattle, 83 p.

BRIGGS, JOHN C.
1953. The behavior and reproduction of salmonid fishes in a small coastal stream. California Department of Fish and Game, Fish Bulletin No. 94, 62 p.

COCHRAN, WILLIAM C.
1943. Analysis of variance for percentage based on unequal numbers. Journal of the American Statistical Association, vol. 38, p. 287-301.

GANGMARK, HAROLD A., and ROBERT D. BROAD.
1955. Experimental hatching of king salmon in Mill Creek, a tributary of the Sacramento River. California Fish and Game, vol. 41, no. 3, p. 233-242.

HOBBS, DERISLEY F.
1937. Natural reproduction of quinnat salmon, brown and rainbow trout in certain New Zealand waters. New Zealand Marine Department, Fisheries Bulletin No. 6, 104 p.

HUNTER, J. G.
1959. Survival and production of pink and chum salmon in a coastal stream. Journal of the Fisheries Research Board of Canada, vol. 16, no. 6, p. 835-886.

KAGANOVSKII, A. G.
1949. Some problems of the biology and population dynamics of pink salmon. Izvestiya tikhookeanskogo nauchno-issledovatel'skogo instituta rybnogo khozyaistva i okeanografii, vol. 31, p. 3-57. (Translation from Pacific Salmon, Published for National Science Foundation and U.S. Department of the Interior by Israel Program for Scientific Translations Jerusalem 1961, p. 127-183.)

MATHISEN, OLE A.
1962. The effect of altered sex ratios on the spawning of red salmon. In Koo, Ted S.Y. (editor), Studies of Alaska red salmon, p. 137-246. Publications in Fisheries, vol. 1, University of Washington, Seattle.

MERRELL, THEODORE R., JR.
1962. Freshwater survival of pink salmon at Sashin Creek, Alaska. In N.J. Wilimovsky (editor), Symposium on pink salmon, p. 59-72. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

McDONALD, J. G.
1960. A possible source of error in assessing the survival of Pacific salmon eggs by redd sampling. The Canadian Fish Culturist, issue 26, p. 27-30.

McNEIL, WILLIAM J.
1962a. Mortality of pink and chum salmon eggs and larvae in Southeast Alaska streams. Ph. D. Thesis, University of Washington, Seattle, 270 p.

1962b. Variations in the dissolved oxygen content of intragravel water in four spawning streams of Southeastern Alaska. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 402, 15 p.

McNEIL, WILLIAM J., and WARREN A. AHNELL.
1964. Size composition of bottom materials in pink salmon spawning beds. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 469, 15 p.

PHILLIPS, ROBERT W., and HOMER J. CAMPBELL.
1962. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. Fourteenth Annual Report of the Pacific Marine Fisheries Commission for the year 1961, p. 60-73.

RICKER, W. E.
1962. Regulation of the abundance of pink salmon populations. In N.J. Wilimovsky (editor), Symposium on pink salmon p. 155-201. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

ROUNSEFELL, GEORGE A.
1957. Fecundity of North American Salmonidae. U.S. Fish and Wildlife Service Fishery Bulletin 122, vol. 57, p. 450-468.

SEMKO, R. S.
1954. The stocks of West Kamchatka salmon and their commercial utilization. Izvestiya tikhookeanskogo nauchno-issledovatel'skogo instituta rybnogo khozyaistva i okeanografii, vol. 41, p. 3-109. (Translated by R. E. Foerster and Leda V. Sagen, Fisheries Research Board of Canada, Translation Series No. 288, 131 p.)

SHERIDAN, WILLIAM L.
1962. Relation of stream temperatures to timing of pink salmon escapements in Southeast Alaska. In N.J. Wilimovsky (editor), Symposium on pink salmon, p. 87-102. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

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